Space Technology Research Grants

A Parallel Boltzmann Simulation for Multi-grid Inertial Electrostatic Confinement Fusion

Completed Technology Project (2013 - 2017)

Project Introduction

Inertial electrostatic confinement (IEC) is a means of confining a non-neutral, non-Maxwellian plasma with an electric field, with the goal of creating fusion energy. The primary application is for the generation of power for high-powered electric propulsion systems on spacecraft. The most basic IEC device consists of two spherical concentric grids, with the inner cathode grid maintained at a lower potential than the outer anode grid to create an electrostatic potential well. To generate fusion events, ions are released from points inside the anode and accelerate towards the core. Counter-streaming ions may collide in the core, producing fusion events. Unfortunately, the energy losses associated with ion thermalization in this two-grid configuration have rendered net power generation impossible. Recent developments in the field of IEC consist of additional concentric grids to focus the ion beams to limit scattering and thermalization. The result is the multi-grid IEC. Added beam-focusing grids have been shown experimentally to increase ion residence times as well as bunch the ions into resonant packets. Over my past year of research, I have created a numerical model of ion transport in the multi-grid IEC system using a numerical approximation to the Boltzmann equation tailored to our system. Ion accelerations in the model are due to the electric field from the charged grids as well as from the space charge of the ions themselves. As the IEC chamber is nearly spherically symmetric, it is only necessary to model one ion packet, with the assumption that counter- and cross-streaming ion packets are identical. The model has also addressed ion-ion coulomb collisions between these packets modeled through the Fokker-Planck-Landau collision operator. The code has been parallelized for GPU processing to mitigate long simulation run-times. Methods to further increase ion confinement times in the multi-grid IEC designs have been proposed, and must be incorporated into my model so that future IEC experimental research can be effectively directed. These methods include the extension of a filament to the device core to maintain a beam-neutralizing electron population, the introduction of permanent magnets to the innermost sphere to further confine these electrons, and the implementation of voltage-oscillating grid potentials to accelerate ions and provide greater control over ion packet formation. To direct this future research, a numerical model is needed to simulate plasma dynamics and optimize system parameters. Electrons will be modeled as an equilibrium solution at each time step, so that the simulation does not have to be resolved to the electron time-scale, and a magnetic force term will be added to the numerical transport equations. The primary purpose of an IEC fusor is the enablement of high powered electric propulsion (EP) thrusters currently in development. As IEC requires vacuum operation, and is easily scaled down without loss of specific power or efficiency, deployment on spacecraft is ideal. The IEC-EP coupling is necessary to reduce launch payload masses and make proposed transits (such as to Mars) more feasible and economical than current specific impulse limited chemical rockets. This motivation is in alignment with the Space Power and Energy Storage Roadmap which delineates the need for a high-power, low-specific mass power

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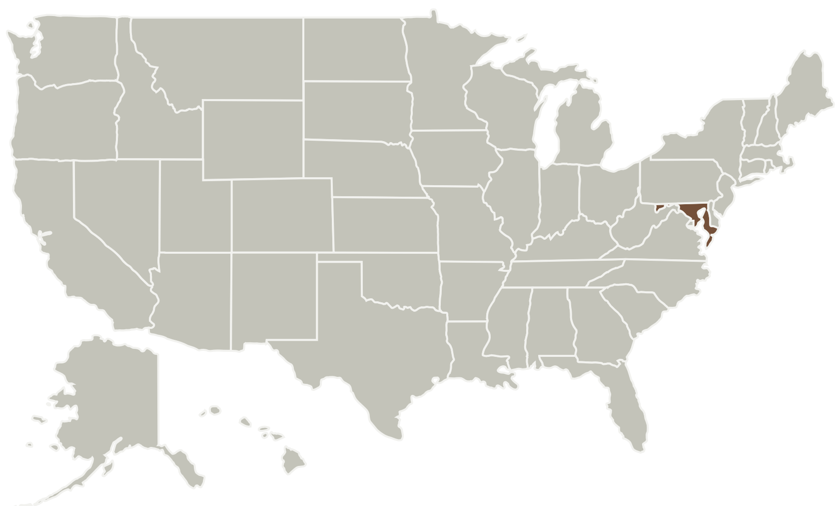
generator to enable future desired missions.

Anticipated Benefits

The Inertial electrostatic confinement electric propulsion (IEC-EP) coupling is necessary to reduce launch payload masses and make proposed transits (such as to Mars) more feasible and economical than current specific impulse limited chemical rockets.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
University of Maryland-College Park(UMCP)	Lead Organization	Academia Asian American Native American Pacific Islander (AANAPISI)	College Park, Maryland

Primary U.S. Work Locations
Maryland

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Organization:

University of Maryland-College Park (UMCP)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

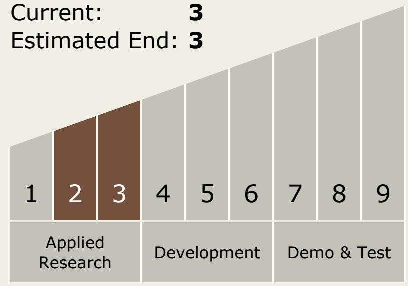
Raymond Sedwick

Co-Investigator:

Andrew M Chap

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX01 Propulsion Systems
  └─ TX01.1 Chemical Space Propulsion
    └─ TX01.1.8 Warm Gas

Target Destinations

Mars, Others Inside the Solar System, Foundational Knowledge